International Conference on Innovative Research in Engineering, Management and Sciences
International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2019 IJSRCSEIT | Volume 4 | Issue 9 | ISSN : 2456-3307

An Experimental Study of Flexural Behavior of Bubble Deck Slab

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ABSTRACT

Reinforced concrete slabs are one of the most common components in modern building construction. Reinforced concrete slabs with plastic voids are a new and innovative type of structural concrete slab system developed to allow for lighter self-weight of the structure while maintaining similar load carrying capacity of a solid slab. Plastic voided slabs are capable of reducing the amount of concrete necessary to construct a building by 30 percent or more. This reduction can be beneficial in terms of financial savings as well as building performance.

This report examines a flexural capacity of two-way reinforced concrete slab with spherical voids in comparison to conventional reinforced concrete slab. The conventional reinforced concrete slab is designed as per the Code provision of IS: 456-2000. For the same depth of slab, 35mm and 40mm diameter spherical voids are created at different spacing at the center of the slab to create voided slab. The slabs are analyzed for different loading and boundary conditions. The geometry of all the slabs was constant 1000x1000x70 mm. The slabs are subjected to nine point bending load/UDL.

Keywords : Bubble Deck Slab(BDS), RC Conventional Slab.

I. INTRODUCTION

In the 1990's, Jorgen Breuning invented a way to link air space and steel within voided biaxial concrete slab. The BubbleDeck technology uses spheres made of recycled industrial plastics to create air voids while providing strength through arch action. As a result, this allows the hollow slab to act as normal monolithic two-way spanning concrete slab. These bubbles can decrease the dead weight up to 35% and can increase the capacity by almost 100% with the same thickness compared to conventional solid slad having same geometry. As a result, BubbleDeck slabs can be lighter, stronger, and thinner than regular conventional reinforced concrete slabs.

Bubble Deck is a revolutionary biaxial concrete floor system developed in Europe. High density polyethylene hollow spheres replace the ineffective concrete in the centre of the slab, thus decreasing the dead weight and increasing the efficiency of the floor. These biaxial slabs have many advantages over a conventional solid concrete slab: lower total cost, reduced material usage, enhanced structural efficiency, decreased construction time, and is a green technology.

Objective and scope

Objective

Objectives of the present investigation are to:

- To obtain the scaled down prototype dimensions of the slab that is to be casted in the laboratory to simulate 9m x 9m x 0.40m slab
- To study the flexural behaviour of two-way Bubble Deck slab of M25 grade of concrete and mild steel reinforcement by varying the percentage of reinforcement at bottom, top and middle layer of slab.
- The bubble deck slabs are comparing with conventional solid concrete slab.

Scope of the study

The experimental studies are carried out to understand the flexural behaviour of two-way Bubble Deck slab. To simulate the 9m x 9m x 0.40m bubble deck slab behavior in the lab, scaled down model of 1m x 1m x 0.07m slab with the scaling factor of 1:7.74 is casted in the laboratory. Flexural tests are carried out on the scaled down slabs for percentage of reduction in concrete volume by 12.28% with the minimum reinforcement of 0.15% of total cross-sectional area cured for a period of 28 days. The test results are compared with conventional solid concrete slab of same dimension.

Methodology

The research methodology is to conduct a literature review of the studies on solid slab and bubble deck slab that have been conducted. On the basis of the literature review, it is realized that the flexural properties of the solid slab and bubble deck slab have been studied by many researchers in different areas of world and still studying; however there still a need to provide experimental and knowledge ground for the use of bubble deck slab in various field. An experimental program was developed to study the flexural properties of bubble deck slab in hardened state. The experimental program included the comparison of ultimate load carrying capacity, deflection and strain between the solid conventional slab and bubble deck slab. Using concrete mixes, test specimens were cast, cured and tested as per the experimental matrix.

Parameters

Figures and Tables

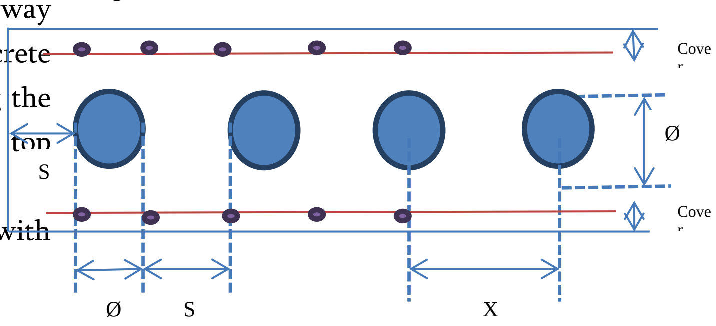

Figure 1 Typical cross section of slab with top and

Middle layer reinforcement spacing

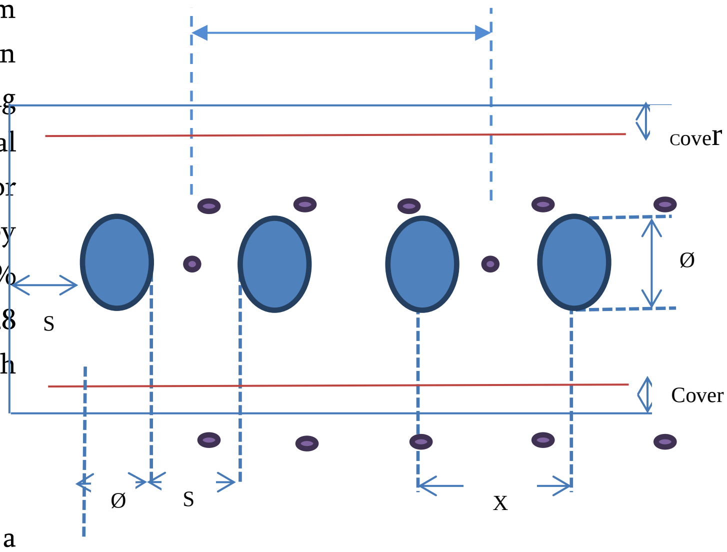

Figure 2 Typical cross section of slab with top, bottom and middle layer reinforcement placed in between balls for all bubble deck slabs

Table 1 Details of Specimen

S N	Slab Specimen/Designation (bottom + middle + top) Reinforcement	% Volume reduction in concrete	No. of plastic balls	Reinforcement		
				Bottom	Middle	Top
1	S_0 (R C Conventional Slab)	0	0	2.6mm@26mm c/c	-	2.6mm @ 52mm c/c
2	S_1	12.28	256	2.6m	-	-

	(Ast +0 +0)			m@26mm c/c		
3	S_2 (Ast +0+ Nominal Ast)	12.28	256	2.6mm@26mm c/c	-	2.6mm @ 52mm c/c
4	S_3 (Ast + ¼ Ast + Nominal Ast)	12.28	256	2.6mm@26mm c/c	2.6 @ 100 mm c/c	2.6mm @ 52mm c/c
5	S_4 (¾ Ast +1/4 Ast +Nominal Ast)	12.28	256	2.6mm @ 34mm c/c	2.6 @ 100 mm c/c	2.6mm @ 52mm c/c
6	S_5 (½ Ast 1/2 Ast +Nominal Ast+)	12.28	256	2.6mm @ 52mm c/c	2.6 mm @ 52mm c/c	2.6mm @ 52mm c/c
7	S_6 (½ Ast + 0+1/2 Ast)	12.28	256	2.6mm @ 52mm c/c	-	2.6mm @ 52mm c/c

Following parameters are considered for the study:

Constant parameters:

- Size of the specimen: 1000mm x 1000mm (925mm effective span) and 70mm (depth)
- Type of the loading: Nine-point load applied at the centre of the slab. The concentrated load from the hydraulic jack is distributed over the nine-steel balls placed over an area of 320mm x 320mm.
- Support conditions: Simply supported on all the four edges of the slab
- Grade of concrete: M25
- Grade of steel: Mild steel bars of 2.6mm diameter
- Plastic balls: 40mm diameter balls
- Spacing of balls: 20mm from edge to edge
- Curing period: 28 days

Variable parameters:

- Varying percentage of Reinforcement.

Results and Discussions

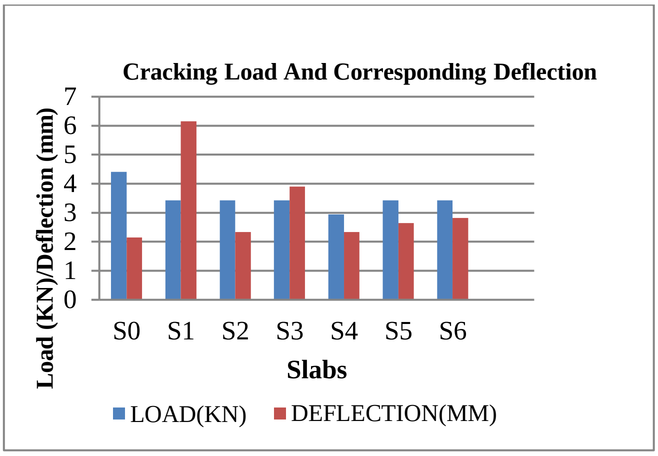

Chart 1 Cracking Load and Corresponding Deflection

It is observed that the first crack appeared on the solid slab (S0) for an applied load of 4.41kN. In Bubble Deck slabs the first crack appeared at 3.43kN (which is 22% less than the RC slab).irrespective of the position of reinforcement

The slab S1 with reinforcement only at bottom layer, Bubble Deck slabs shows more deflection than RC slab by 65%. With reinforcement at the middle layer of the slab, S3, S4 and S5 have shown the deflection of 3.90mm, 2.33mm and 2.64mm respectively at the appearance of first crack. Bubble deck slab without reinforcement at the middle layer of the slab S1, S2 and S6 have shown deflection of 6.15mm, 2.34mm and 2.82mm respectively. However the deflection in the bubble deck slabs is higher than the RC slab this may due to the presence of plastic balls which is making Bubble Deck slab to behave like a spatial structure and forces are getting distributed within the slab in a better way, in turn increasing the slab strength. Bubble deck slabs with bottom and top reinforcement, with and without middle layer reinforcement deflected by 44% higher than the RC slab.

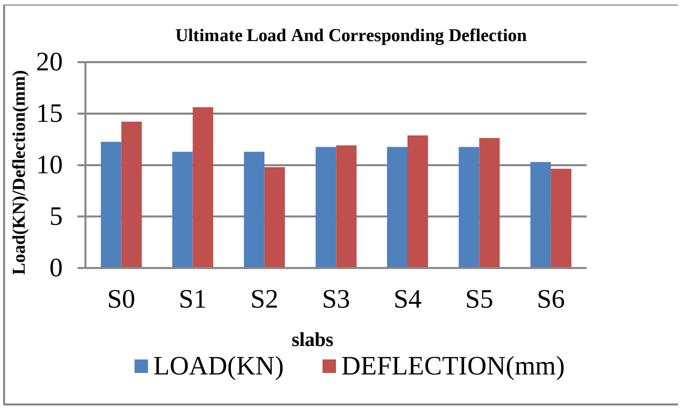

Chart 2 Ultimate Load And Corresponding Deflection

It is observed that ultimate load of RC conventional slab (S0) is 12.74kN, and the ultimate load of the bubble deck slabs is 4% to 8% less when compared with a RC conventional slab (except S6 slab which 16% less).

The ultimate load of Bubble Deck slabs with middle layer of reinforcement i.e. S1, S2 and S6 is 11.72KN, 11.72KN and 10.70KN respectively. The ultimate load of Bubble Deck slabs without middle layer of reinforcement i.e. S3, S4 and S5 is 12.23KN for all slabs. From this result an inference can be drawn that the presence of middle layer of reinforcement in bubble deck slabs resist more load. The maximum deflection of RC conventional slab (S0) is 14.23mm. Table 5.25, bubble deck slabs (S1) with only bottom layer reinforcement deflect more than the RC conventional slab by 8.8%. Bubble Deck slabs with reinforcement at bottom, top and middle layer S3, S4, and S5 deflects less than RC slab varying between 9.8 to 16%.the bubble deck slab with bottom and top reinforcement deflects by 31% less than the RC slab.

Based on the above result it is found that the bubble deck slab with reinforcement at bottom, top and middle layer of reinforcement deflects almost same as RC conventional slab. The bubble deck slab with only bottom reinforcement carries more load and deflects more.

This behavior might be due to Bubble Deck slab capable of taking service loads more than RC conventional slab, and forces getting distributed within the slab in a better way due to the presence of plastic balls at the centre of the slab. The above results indicate that insertion of plastic balls in the centre of the slab has nearly same load carrying capacity as that of RC conventional slab.do not affects the strength of the slab, this may be due to the action of the plastic balls as spatial structure.

Conclusion

The conclusions pertaining to comparison of flexural behavior of Bubble Deck slab are listed below.

- The flexural behavior of the Bubble Deck slab is considerably good in comparison to the Conventional RC Slab.
- In the present study by introducing voids into the RC conventional slab, the self-weight of the slabs can be reduced up to 10.91% and it is concluded that voided slab can be used to reduce the structure weight with minimal impact to the overall building design and also greatly reduce the overall weight of the slab while meeting load capacity requirements.
- Bubble deck slabs have shown reduced noise levels in comparison with RC conventional slab. The slab (S1) has shown a better result with 2.14% of noise reduction
- Bubble deck slabs have shown reduction in volume up to 12.28% when compared with conventional RC slab resulting in reduction in dead load of the slabs.
- First crack load of all bubble deck slabs irrespective of reinforcement remains same, 22.22% less than the first crack load of RC conventional slab.
- The deflection at first crack of bubble deck slab were remains same and 15% higher than deflection of RC conventional slab, however slab (S1) which is nearly 65% more deflection than RC conventional slab.
- The ultimate load of all bubble deck slabs shown almost same as RC conventional slab. The ultimate load of bubble deck slabs 4% less than RC conventional slab and the deflection at the

ultimate load of all bubble deck slabs 32.32% lesser than the RC conventional slab except slab (S1) which is 8.84% more deflection than the RC conventional slab.

- The ultimate load of bubble deck slab with bottom and top reinforcement and without middle reinforcement 8% less than the RC conventional slab except (S6). Whereas bubble deck slab with bottom, middle and top reinforcement is 4% less than the RC conventional slab. The deflection at ultimate load with only bottom reinforcement is 8.84% higher than the RC conventional slab. The deflection of bubble deck slab with bottom, middle and top reinforcement is 10% less than the RC conventional slab.
- RC conventional slab is rigid along the yield line and flexible at the center and along the X-line. Whereas bubble deck slab with only bottom reinforcement and bottom and top reinforcement are flexible along the centre, yield line and X-line. The bubble deck slab with bottom, middle and top reinforcement are rigid along the yield line similar to RC conventional slab, however the rigidity is less than the RC conventional slab.
- Off all bubble deck slab with different position of reinforcement S2 slab with designed reinforcement at bottom and nominal reinforcement at top resist only 4% less load than RC conventional slab and deflection is 31% less than RC conventional slab. And it is flexible at the centre, along the X-line and along the yield line.
- Slabs with bottom, middle and top layer reinforcement behaves similar to RC conventional slab with 4% less load carrying capacity and 9.5% less deflection and the flexibility of slab is little higher than the RC conventional slab.
- S6 slab with designed reinforcement distributed half at bottom and top shows least performance having 16% less and 32% less deflection and it is very rigid.
- Bubble deck slab with only bottom reinforcement has the load carrying capacity nearer to RC conventional slab with 8% variation and with higher deflection 8% greater than the RC slab it is flexible along the yield line controversial to RC conventional slab.
- Bubble deck slab (S1) with having only bottom reinforcement which shows the better load carrying capacity compared to RC conventional slab. And it is 22.22% less at cracking load and ultimate load when compared to RC conventional slab.
- Bubble deck slab (S1) having only bottom reinforcement deflection at cracking load and ultimate load is 65% and 8.84% more than the RC conventional slab. This indicates that the bubble deck slab (S1) is more flexible because of only bottom reinforcement.
- This behaviour might be due to the presence of tension reinforcement (Ast) and compression reinforcement(nominal reinforcement) which is making Bubble deck slab to behave like a spatial structure and forces are getting distributed within the slab in a better way
- Structural design and detailing of bubble deck slab is straight forward.

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